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MACHINE LEARNING MODELS IN PULSE TIG WELDING OF TITANIUM ALLOY

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ABSTRACT

Titanium is one of the most important non-ferrous metals, which finds extensive application in the aerospace industry, because of its lightweight, excellent corrosion resistance, high strength level. Pulsed current tungsten–inert-gas welding is widely used in manufacturing important structures and products because it has quite a few advantages and practical benefits. With this process, it is easy and convenient to control heat input into parent materials and weld formation, to improve arc stability, to reduce thermal distortion and to achieve fine grains in the weld zone. Important process parameters from the previous investigation are identified and an experimental plan is derived to perform the experiments.

Machine learning is a beneficial method to solve problems faced in welding processes. It can improve the welding process effectiveness as well as the process of quality monitoring. Machine learning models developed will optimize the parameters to give better mechanical properties.

Keywords: Titanium alloy welding, machine learning models parameters for good mechanical properties.

I. INTRODUCTION

Two techniques pulsing of current and oscillation of arc have gained importance due to their promise and the ease with which these techniques can be utilized to industrial situations with only minor modifications to the existing welding equipment [1]. Current pulsing is used in often [2-5] to alter the grains. Significant refinement of the solidification structure has been reported in titanium alloys, aluminium alloys, austenitic stainless steels, nickel base alloys and high strength steels. Due to its high strength-to-weight ratio and superior corrosion resistance, titanium is common in the fabrication of industrial machineries, turbines, spacecrafts etc., the most commonly preferred welding processes for welding titanium alloy are: (i) Gas Tungsten Arc Welding (GTAW) and (ii) Electron Beam Welding (EBW). Due to higher equipment cost and initial investment requirements, the EBW process is not widely used [6-7]. Moreover EBW process has certain limitations in welding complicated structures due to the requirement of vacuum chamber. On the other hand, GTAW process is more versatile and it can be employed at any place. Pulsed current GTAW process is more economical to refine the fusion zone microstructure of titanium alloys.

However, the reported literatures on pulsed current GTAW process could be counted with finger. Due to this the current study stands importance

(i) Studying the influence of pulsing and the associated parameters to understand the mechanical properties.

(ii) Developing machine learning models to predict mechanical properties of pulsed current GTA welded Ti-6Al-4V alloy by incorporating pulsed current parameters.

II. MATERIALS AND METHODS

A. Materials under investigation

The material used for the current work is a commercially available and widely usable titanium alloy of Ti-6Al-4V grade. This material is selected for its wide application in various fields. This is popular among various non ferrous materials and finds application in various sector

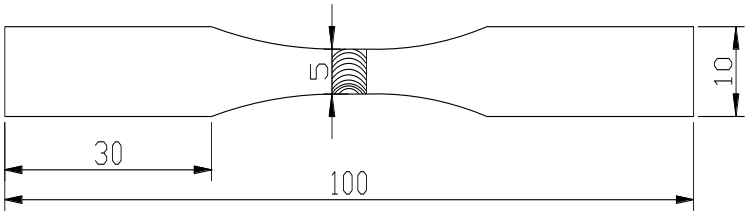
B Experimental Work

The welded joints were sliced and then machined using wire cut electric discharge machining (EDM) to the required dimensions for preparing tensile, impact and corrosion specimens. Transverse tensile specimens were prepared as shown in Figure 1(a). ASTM E8M-90a (1991a) guidelines were followed for preparing the test specimens.

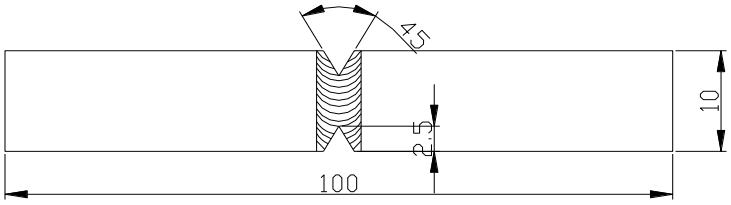
Further, the smooth (unnotched) tensile specimens were prepared to evaluate transverse tensile properties of the joints such as yield strength, tensile strength and elongation.

However, the notched specimens were prepared to evaluate notch tensile strength and notch strength ratio of the joints. Sub-size Charpy impact specimens were prepared to evaluate the toughness of the base metal and ASTM E23-91 (1991b) specifications were followed. The dimensions of the Charpy impact specimen are shown in Figure 1(b).

The important factors influencing the experimentation is produced in Table 1. Experiments were conducted as per Table 2 and corresponding results were recorded.



(a) Smooth (Unnotched) Tensile Specimen



(b) Sub-size Impact Specimen

(All dimensions are in mm)

Figure 1 (a-b) Dimensions of various test specimens

Table 1 Important parameters and their working range

S. No.	Factor	Notation	Unit	Levels				
				(-2)	(-1)	(0)	(+1)	(+2)
1	Peak Current	P	Amps	55	65	75	85	95
2	Base Current	B	Amps	15	25	35	45	55
3	Pulse Frequency	F	Hz	0	3	6	9	12
4	Pulse on time	T	%	30	45	40	45	50

III MACHINE LEARNING MODELS

Data preprocessing is done to remove noise in the unstructured data and normalize to improve the efficiency of the machine learning algorithm. Null Values are removed by applying interpolation methods. Once the data is cleaned and made free of null values. Data is processed by applying Standard Scaler (Normalization using standard deviation) which brings the values under normal distribution. After normalization the feature values would fit in normal distribution which allows novel machine learning algorithms to its utmost potential.

MODEL SELECTION AND IMPLEMENTATION

The above problem is viewed as a regression problem in which the main aim would be predicting the tensile strength, elongation and impact strength.

The algorithms are developed with the help of sklearn, scipy and tensorflow.

SKLEARN

Scikit-learn (Sklearn) is the most useful and robust library for machine learning in Python. It provides a selection of efficient tools for machine learning and statistical modeling including classification, regression, clustering and dimensionality reduction via a consistent interface in Python.

TENSORFLOW

Tensor Flow is used as a machine learning platform for the study. It is used for machine learning applications. Research on AI gave a break through to the Google team in the form of TensorFlow. TensorFlow is utilized in the Python language for the specific applications

SCIPY

SciPy, a Python scientific library, is a free and open source library for mathematics, science, and engineering. NumPy, which provides convenient and fast N-dimensional array manipulation, is used by the SciPy library. The main reason for creating the SciPy library was to make it compatible with NumPy arrays. It includes many user-friendly and efficient numerical practises, such as numerical integration and optimization routines. Table 3 shows the optimised values based on the models mentioned above.

IV.RESULT AND DISCUSSION

Table 2 Experimental Output

ORIGINAL VALUES				OUTPUT VALUES			
P (Amp)	**B (Amp)**	**F (Hz)**	**T (%)**	**Yield Strength (MPa)**	**Tensile Strength (MPa)**	**Elongation (%)**	**Impact Toughness (J)**
70	30	3	40	958	1020	3.7	7
90	30	3	40	1001	1060	4.6	10
70	50	3	40	952	1000	3	6
90	50	3	40	995	1040	4.25	9
70	30	9	40	992	1030	4	8
90	30	9	40	1041	1075	4.85	10
70	50	9	40	978	1015	3.5	7
90	50	9	40	1014	1060	4.6	10
70	30	3	50	957	1005	3.2	7
90	30	3	50	987	1045	4.4	9
70	50	3	50	931	990	2.5	6
90	50	3	50	969	1025	3.85	8
70	30	9	50	961	1010	3.4	7

90	30	9	50	1014	1060	4.65	9
70	50	9	50	959	995	2.75	6
90	50	9	50	1008	1040	4.3	9
60	40	6	45	1065	1100	5.15	10
100	40	6	45	1030	1070	4.85	8
80	20	6	45	1070	1120	5.4	11
80	60	6	45	1035	1090	5	10
80	40	0	45	923	975	2.4	7
80	40	12	45	940	1000	2.8	9
80	40	6	35	1046	1110	5.3	10
80	40	6	55	1026	1080	5	9
80	40	6	45	1080	1140	5.8	12
80	40	6	45	1100	1120	5.1	11
80	40	6	45	1075	1150	5.6	11
80	40	6	45	1060	1135	5.9	12
80	40	6	45	1110	1160	5.8	11
80	40	6	45	1090	1115	5.3	12
80	40	6	45	1085	1155	5.1	13

Design of Experiments concept is found to be more economical and efficient to develop mathematical models by conducting an optimum number of experiments [8-11].

The strength increased during the operating frequency of 0 to 6Hz. Strength dipped during the frequency range of 6 to 12Hz. During the rise of base current, the tensile strength went down by 3.04% when related to the tensile strength seen at a pulse on time of 45%.

Rise in pulse on time by 57%, resulted in decrease of strength by 2.91% when compared at a constant base current of 40 amps. Rise in peak current from 60 to 80amps, the tensile strength shows increasing trend and between 80 to 100 amps, tensile strength decreases.

The ductility raised during the pulse frequency range of 0 to 6Hz. It is also noticed that the ductility tend to dip for an increase in pulse frequency between 6 to 12Hz. Rise in base current resulted in decrease of ductility by 15.64% .

Rise in pulse on time by 57%, resulted in reduction of ductility by 13.76% when related to the highest percentage of elongation obtained at constant base current of 40 amps. Increase of peak current in the range of 60 to 90 amps, ductility is found to increase and when raised from 90 to 100 amps, ductility decreased without having any effect with change in base current and pulse on time.

When peak current is increased from 60 to 80amps, the impact toughness increases and then decreases irrespective of changes observed in pulse on time and base current. The impact toughness decreases by 15.1%, when the pulse on time is increased by 57%, as compared to the highest value of impact toughness observed at constant base current of 40 amps.
Impact toughness increases initially for the values of pulse frequency between 0 to 6Hz and then decreases. The impact toughness falls down by 8.45%, when the base current is raised by 200% at 45% pulse on time.

However, from the results it is evident that the pulsed current parameters have greater influence on mechanical and metallurgical properties. The enhancement in mechanical properties such as tensile properties, impact toughness and weld metal hardness are mainly due to the refinement in fusion zone grain size. Hence, the basic reason for the improvement in mechanical properties is the refinement produced in fusion zone grain size by pulsed current welding technique. The mechanism involved in grain refinement by pulsing current is explained in detail below. The amplitude of thermal oscillations has been found to increase with increasing ratio of the peak to base currents and to decrease with rising pulse frequency. Change in temperature because of pulsing resulted in the solidification process. When the pulsing reduces the interface of solid and liquid moves towards the arc and creates disturbances to the arc form. Transfer of heat along the weldment and base metal changes the micro structure and hence the property of the material. At present the increased effort to develop mathematical models is to achieve quality weldment.

In general, the formation of equiaxed grain structure in CCGTA weld is known to be difficult because of the remelting of heterogeneous nuclei or growth centers ahead of the solid-liquid interface. This is due to the high temperatures in the liquid, thus making survival nuclei difficult. As the pulse peak current decays, the solid-liquid interface advances towards the arc and increasingly becomes vulnerable to any disturbances in the arc form. As current increases again in the subsequent pulse, growth is arrested and remelting of the growing dendrites can also occur. Pulsing the current varies the arc force. Temperature also keeps on varying which changes the pool size and shape resulting in formation of new grains. The heat imparted per volume of weld pool seems to be less in pulsing.

Table 3 Optimized Output

	Factors				
Response	**P (Amps)**	**B (Amps)**	**F (Hz)**	**T (%)**	**Optimum Value**
Yield Strength	82.5	37.3	6.2	44.1	1086 MPa
Tensile Strength	82.9	37.2	6.21	43.9	1143 MPa
Elongation	88	34.4	6.25	42.9	5.75%
Impact Toughness	83.78	48.65	6.52	43.95	12.9 Joules

V CONCLUSIONS

Titanium alloy is widely used for many industrial applications. Welding of the materials needs careful consideration of the process parameters. Machining learning models have been utilized in identifying the important parameters to optimize the same to yield good tensile properties. Following are the conclusions drawn out of the current investigation.

a) Current pulsing seems to be playing an important role in maximizing the tensile properties
b) The maximum improvement obtained in tensile strength is 19%, and elongation is 140%;
c) Impact toughness is 86% as compared to constant current welding.

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